Nonlinear viscoelastic damping for seismic isolation

Nicola Menga[1,2], Francesco Bottiglione[1] and Giuseppe Carbone[1]
[1]*Department of Mechanics, Mathematics and Management, Politecnico di Bari, Bari, Italy*
[2]*Department of Mechanical Engineering, Imperial College London, London, UK,*

Abstract. The aim of the research here presented is to explore the effectiveness of nonlinear base isolation in controlling seismic vibration. Specifically, we adopt a Rubber-Layer Roller Bearing (RLRB) with both nonlinear stiffness and non-monotonic viscoelastic damping. Indeed, the rolling contact between the rigid rollers and the viscoelastic pads occurring in the RLRB leads to a bell-shaped damping response, with the damping force initially increasing with the relative velocity increasing up to a peak value, and then fast decreasing. Since real seismic excitation spectra are unknown, we focus on the robustness of the isolation performance with respect to different input. Indeed, we firstly perform a global optimization of both the nonlinear RLRB isolator and a generic linear one over a set of five seismic shocks; then, we compare the isolation performance of the two systems with respect to each of the shocks.

Introduction

Nonlinear base isolation is one of the most promising strategy to control ground vibration, mostly by relying on Rolling Isolation Systems (RIS) [1]. Among them, RLRBs deserve special mention [2], due to their intrinsic ability to provide nonlinear damping. Indeed, in these devices rigid rollers are forced into contact with a rigid plate coated with highly viscoelastic polymers. As relative velocity happens between the rollers and the plate due to external forcing, rolling viscoelastic contact occurs, thus leading to non-monotonic bell-shaped damping force, whose specific trend depends on the material relaxation time τ and rollers spacing λ. Here we rely on a RLRB, associated to a nonlinear cubic spring, to base-isolate from ground vibration a simple heavy inertial mass supported by an elastic beam (see Figure 1a). The physical system can be therefore modelled by a two dofs lumped scheme, with both nonlinear stiffness and damping (see Figure 1a).

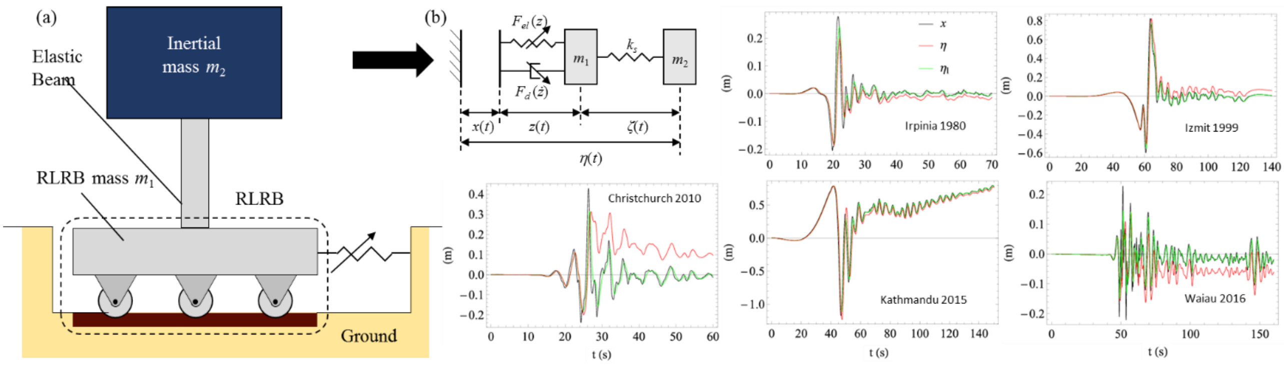

Figure 1: a physical (a) and lumped (b) scheme of the system under investigation. Diagrams show the system response to five different seismic shocks.

Results and Discussion

We investigate the dynamic response of the system under seismic base excitation. Specifically, we consider a set of five different shocks, and we perform a global optimization of the isolation damping (i.e. τ and λ) and stiffness (i.e. k_s) with respect to the overall isolation performance. The latter is calculated in terms of the peak and the root mean square values of the inertial forces acting on the isolated mass m_2, together with the relative displacement between the structure base and the ground. Finally, we compare the optimized results of the nonlinear RLRB isolator with those of a generic linear isolator on each single shock (see diagrams in Figure 1). The comparison highlights a more robust performance associated to the nonlinear system compared to a generic linear one; indeed, the former appears able to better tolerate a variation of the specific excitation spectrum. Such a result is peculiar of nonlinear system with non-monotonic damping (e.g. viscoelastic friction), and may be of interest for several applications (e.g. seismic, marine, wind engineering) in which stochastic non-stationary excitation occurs. Indeed, in this case, the design of the isolation system can only count on statistical data, and isolators with the broadest effective frequency bandwidth are the preferred choice.

References

[1] PS Harvey, KC Kelly. (2016) A review of rolling-type seismic isolation: Historical development and future directions. *Eng Struct*, **125**.
[2] N Menga, F Bottiglione, G Carbone. (2019) The nonlinear dynamic behavior of a Rubber-Layer Roller Bearing (RLRB) for vibration isolation. *J Sound Vib* **463**:114952.